Global Environmental Change 54 (2019) 160–171

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

Adapting and coping with climate change in temperate forests

Alexandra Paige Fischer

School for Environment and Sustainability, University of Michigan, 440 Church Street, Ann Arbor, MI, 49109, United States

ARTICLE INFO

Keyword:
Climate change
Adaptation
Temperate forests
Private forest owners
Behavioral strategies

ABSTRACT

A growing body of research documents how individuals respond to local impacts of global climate change and a range of policy efforts aim to help individuals reduce their exposure and improve their livelihoods despite these stressors. Yet there is still limited understanding of how to determine whether and how adaptation is occurring. Through qualitative analysis of focus group interviews, I evaluated individual behavioral responses to local forest stressors that can arguably be linked to global climate change among landowners in the Upper Midwest, USA. I found that landowner responses were planned as well as autonomous, more proactive than reactive, incremental rather than transformational, and aimed at being resilient to change and transitioning to new conditions, rather than resisting change alone. Many of the landowners' responses can be considered forms of adaptation, rather than coping, because they were aimed at moderating and avoiding harm on long time horizons in anticipation of change. These findings stand in contrast to the short-term, reactive, and incremental responses that current socio-psychological theories of adaptation suggest are more typical at the individual level. This study contributes to scientific understanding of how to evaluate behavioral adaptation to climate change and differentiate it from coping, which is necessary for developing conceptually rigorous analytical frameworks to guide research and policy.

1. Introduction

As society increasingly recognizes the need to learn to live with the effects of climate change, researchers and practitioners seek to better understand adaptation across all levels of social organization (Adger et al., 2009; Moser, 2010). Adaptation among individuals, including members of households and extended families, is especially important because it is the level at which people most directly experience environmental change and engage in behavioral change. However, it is generally assumed that, without policy interventions, adaptation does not readily occur in a planned, proactive, and transformational fashion among individuals because individuals tend to respond incrementally to environmental changes that are of immediate concern and personal relevance and that they perceive themselves as being capable of addressing (Grothmann and Patt, 2005; Adger et al., 2009; Berrang-Ford et al., 2011; Ford et al., 2011; Gifford et al., 2011; Moser and Dilling, 2004). Climate change, on the other hand, is a complex long-term phenomenon consisting of interacting local, regional, and global conditions and processes that individuals are typically unsure how to address.

A growing body of research seeks to better understand behavioral response to climate change (i.e., at the level of individuals), and a variety of policy efforts aim to help individuals reduce their exposure and improve their livelihoods in spite of adverse impacts. However, these scholarly and practical efforts are constrained by a lack of conceptually rigorous frameworks for evaluating whether and how adaptation occurs. Although, in theory, individual adaptation refers to the process by which people make long-term behavioral adjustments to reduce the adverse impacts of experienced or anticipated change and to maintain or increase their suitability to the environment (Smit et al., 1999; Sober, 1993; Fankhauser et al., 1999; Adger et al., 2005; Field et al., 2014), in practice, the term adaptation is used to refer to a wide variety of short- and long-term behavioral responses without regard for outcomes (Fazey et al., 2010). In some cases, the responses that scholars and policymakers refer to as "adaptations" may be more aptly termed "coping"—short term, reactive efforts enacted quickly to ward off immediate impacts (Smit and Wandel, 2006; Blaikie et al., 1994; Birkmann, 2011)—or even "maladaptation," in which efforts to adapt have the unintended result of increasing the vulnerability of others (Barnett and O'Neill, 2010; Juhola et al., 2016).

It is important to systematically characterize people's responses to climate change and to distinguish between adaptation and coping because doing so makes it possible to evaluate policy and societal progress toward learning to live and thrive, despite change (Adger et al., 2005; Ford and Berrang-Ford, 2016). For example, in developed nations, where technology and infrastructure buffer individuals from many

E-mail address: apfisch@umich.edu.

https://doi.org/10.1016/j.gloenvcha.2018.10.011
Received 10 June 2018; Received in revised form 16 August 2018; Accepted 26 October 2018
Available online 20 December 2018
0959-3780/

climate change impacts, incentive- and capacity-building programs may be needed to reduce the psychological distance of climate change and catalyze action (Adger et al., 2009; Wolf and Moser, 2011; Fankhauser et al., 1999). Policy initiatives that conflate coping with adaptation may be inefficient and potentially even counterproductive because they can foster short-term, temporary adjustments rather than enduring behavioral change. Despite the need for a better understanding of adaptation among individuals, empirical research on individual adaptation is limited. As of 2011, only 11 empirical research papers had reported on individual adaptation actions (Berrang-Ford et al., 2011; Ford et al., 2011), and as of 2018, it appears that few additional papers have been published.

This empirical research paper aims to improve scientific understanding of how individuals respond to climate change and how adaptation responses differ from coping responses. I investigated how individual landowners adjust their forest management behaviors in response to local forest stressors that are arguably linked to global climate change and how their responses exhibit key elements of adaptation behavior according to published typologies for classifying generic types of adaptation and distinguishing between adaptation and coping (e.g., (Fankhauser et al., 1999; Smit et al., 2000). The findings provide insight into how conceptually rigorous analytical frameworks can inform evaluations of whether and how adaptation occurs at the individual level.

2. Relevant literature

2.1. Characterizing adaptation behavior

A number of typologies have been developed for classifying generic types of adaptation and distinguishing between adaptation and coping (e.g., Fankhauser et al. (1999); Smit et al. (2000); Birkmann (2011); Burton et al. (1993); Klein (2003). These typologies characterize adaptation behavior on three dimensions: purposefulness, timing, and scope. Regarding purposefulness, adaptation can be autonomous, at one extreme, or planned, at the other. Autonomous adaptation entails the spontaneous or ongoing implementation of existing knowledge and techniques, whereas planned adaptation involves intentional efforts to engage information about present and future change in consideration of the suitability of current and planned practices and policies (Füssel, 2007; Smit et al., 2000; Birkmann, 2011; Fankhauser et al., 1999), often with direct government assistance (Klein, 2003). Regarding timing, adaptation can be reactive or proactive. Reactive adaptation refers to an immediate behavioral response to regain stability, often through spreading risk and securing resources. In contrast, proactive adaptation entails reorienting practices in anticipation of new conditions in order to reduce future damage, risk, and vulnerability, often through planning, monitoring, increasing awareness, building partnerships, and learning (Smit et al., 2000; Berrang-Ford et al., 2011; Ford et al., 2011; Fankhauser et al., 1999). Regarding scope, adaptation can be incremental or transformational. Incremental adaptation refers to making small changes in current contexts to avoid disruptions and continue pursuing the same objectives, whereas transformative adaptation entails making changes at large scales that are new to a particular context and that fundamentally change the broader biophysical, social, or economic system (Park et al., 2012; Pelling et al., 2015; Kates et al., 2012). In the context of forests, adaptation frameworks also distinguish between adaptation strategies based on the implicit goals of adaptation: whether adaptation aims to buffer or protect forests from change (i.e., promote resistance), improve the capacity of ecosystems to recover from climate “shocks” (i.e., promote resilience), or facilitate change (i.e., enable transition) (Millar et al., 2007; Keenan, 2015; Joyce et al., 2009; Janowiak et al., 2014b). Characterizing behaviors within a hierarchy of basic analytical units of social behavior has also been recommended (Fischer, 2018)—namely as practices, which are patterned and routinized behaviors driven by purposes or norms and implemented through activities (Schatzki, 1997; Reckwitz, 2002; Giddens, 1979, 1989), and strategies, which are the mechanisms or processes governing the relationship between the practices and the goals they serve.

2.2. Distinguishing between adaptation and coping

Characterizing behavioral responses to climate change with typologies may also help differentiate between adaptation and coping behavior. Adaptation is generally distinguished from coping based on the temporal scale at which it occurs. Adaptation is referred to as a long-term process of enduring adjustment, whereas coping is considered a short-term process of temporary adjustments (Smit and Wandel, 2006; Gallopín, 2006; Blaikie et al., 1994; Opiyo et al., 2015; Birkmann, 2011). Manipulation of an external system to make self-regulation unnecessary (Thomsen et al., 2012) can also be viewed as coping, as when land managers suppress wildfires to protect forests—and the people who live in them—in the near term, even though this approach may allow for the accumulation of flammable vegetation that could fuel larger and more severe wildfires in the future (Fischer et al., 2016). In cases where such near-term risk mitigation efforts by one set of actors exacerbates risks in the future for another set of actors, coping can also contribute to maladaptation. Adaptation can also be distinguished from coping on the basis of the timing of the responses, which can arguably be related to the organizational scale at which the response occurs. Adaptation is generally associated with action in anticipation of a threat, which often requires information and resources held collectively by institutions, whereas coping is associated with reactive responses that can be quickly implemented (Osbahr et al., 2008). Thus, behavioral responses that are extremely autonomous, reactive, and incremental might be better termed as coping, whereas responses that are highly planned, proactive, and transformational could be treated as adaptation.

2.3. Adaptation among individuals

Behavioral adaptation is generally expected to consist of autonomous, reactive, and incremental behaviors, as these are more consistent with the capacities and cognitive tendencies of individuals; on the other hand, planned, proactive and transformational adaptation is considered the domain of institutions, which maintain complex knowledge and have the capacity to facilitate long-term strategic planning (Fankhauser et al., 1999; Smit et al., 1999; Berrang-Ford et al., 2011; Ford et al., 2011). Indeed, much of the empirical literature on climate change adaptation among individuals documents reactive and incremental responses to existing stimuli rather than proactive, transformational responses in anticipation of future impacts (Toole et al., 2016; Ford et al., 2011; Berrang-Ford et al., 2011; Ford et al., 2011; Wise et al., 2014). This may be attributable, in part, to the fact that some research on individual adaptation is conducted in the context of short-term climate variability and extreme events (Berrang-Ford et al., 2011; Ford et al., 2011; Wise et al., 2014), such as floods and storms (Kelly and Adger, 2000; Nguyen et al., 2013), heat waves (Wolf et al., 2010), and droughts (Zheng and Dallimer, 2016; Head et al., 2011; Truelove et al., 2015). However, a number of studies focus on the broader temporal and spatial dimensions of climate change, such as long-term changes in temperature and precipitation (Shameem et al., 2015; Deressa et al., 2009; Wheeler et al., 2013; Wood et al., 2014; Raymond and Robinson, 2013) and weather patterns (Barbier et al., 2009), sea level rise (Md Mustafa and Jayant, 2010), plant composition, and pests and diseases (Lawrence and Marzano, 2014; Blennow, 2012; van Gameren and Zaccai, 2015). Few studies of individual adaptation evaluate responses with published typologies. Exceptions include van Gameren and Zaccai (2015); Zheng and Dallimer (2016), and Grothmann and Patt (2005), which distinguish between autonomous and planned adaptation, as well as proactive and reactive adaptation. In addition, Raymond and

Robinson (2013) and Wheeler et al. (2013) distinguish between autonomous and planned adaptation and between incremental and transformational adaptation. These studies, however, do not distinguish between adaptation and coping or specify underlying adaptation goals.

2.4. The case of temperate forests

Temperate forests offer an important and useful context in which to investigate adaptation at the individual level. Global changes in temperature and precipitation are expected to adversely affect tree species in many areas, increasing their vulnerability to direct physiological stress and climate-mediated stressors, such as wildfires, storms, droughts, and pest and disease outbreaks (Seidl et al., 2017; Allen et al., 2010; Millar et al., 2007). Forests are particularly sensitive to climate change because the long life span of trees does not allow for rapid biological adaptation (Kolström et al., 2011). Moreover, the spatial and temporal scales of climate change impacts on forests challenge the scales on which individuals are expected to respond to climate change. The types of impacts that temperate forests may experience are a function of complex interactions between global changes in temperature and precipitation and local disturbance processes. Given that conditions (wildfire hazard, drought stress) that make forests vulnerable to such disturbances develop over long time horizons and large spatial extents, adaptation requires not only short-term responses to natural hazard events but also long-term planning and management on large landscapes consisting, in some cases, of multiple ownerships.

3. Approach

3.1. Research questions and objectives

This study builds on the growing body of empirical research and theory that seeks to improve our understanding of whether and how individuals adapt to climate change. In particular, I investigated how to characterize behavioral responses to the local impact of global climate change on forests and how to distinguish adaptation from coping. Focusing on individual landowners in the temperate forest biome, I pursued three research questions:

1 How have forest landowners adjusted their forest management behaviors in response to forest stressors that can arguably be linked to global climate change?
2 What key elements of adaptation behavior do landowner responses exhibit?
3 How do landowner responses constitute adaptation as opposed to coping?

Using an inductive approach consisting of focus group interviews, qualitative content analysis, and grounded theory, I sought to document landowner responses to forest stressors and then (a) characterize the responses in terms of emergent (a priori) categories of forest management behavior, (b) characterize their responses in terms of predetermined (a posteriori) categories of adaptation behavior (i.e., from the scholarly literature), and (c) distinguish their responses on the basis of adaptation versus coping.

3.2. Study area

The geographic focus of the research was the Northwoods, an area within the Laurentian mixed forest ecosystem at the northern edge of North America's temperate forest biome in the US Upper Midwest (Fig. 1). Five forest subtypes are interspersed across the Northwoods according to micro-topographic relief and historical land use: maple-beech-birch, jack-red-white pine, spruce-fir, oak-hickory, and aspen-birch. Like other temperate forests, the Northwoods is projected to experience stressors such as wildfires, storms, droughts, and pest and disease outbreaks on larger scales and with greater severity than in the past (Seidl et al., 2017; Millar and Stephenson, 2015). Climate models project a hotter, more arid climate in this area over the next century, with conditions that will interact with other disturbance processes—both global (e.g., invasions by exotic pests and diseases) and local (e.g., wildfires, storms, droughts)—resulting in the decline of many tree species (Hayhoe et al., 2010; Duveneck and Scheller, 2016; Handler et al., 2014a, b; Janowiak et al., 2014a). Many local impacts of climate change have already been observed in the region, including longer growing seasons; wildlife and plant species range shifts; increasing temperatures, especially in winter and spring; increasing precipitation, particularly in summer and fall; and heavier rainfall events (Janowiak et al., 2014a; Handler et al., 2014a; Handler et al., 2014b). Invasive insects and diseases, which proliferate more easily in warmer and wetter conditions, are considered the greatest threats to forestland in this area (Hubbart et al., 2016; Poland and McCullough, 2006). Emerald ash borer, beech bark disease, oak wilt, and hemlock woody-algid have already infested much of the area's forestland. Although less salient, wildfire has been another concern in some parts of the study area (Cleland et al., 2004; Haight et al., 2004).

The local impacts of climate change that are expected to occur in the Northwoods may adversely affect landowners by threatening economically important species and complicating forestry operations (e.g., logging in wetter, warmer winters) (Irland et al., 2001; Lal et al., 2011). Individual owners of small, forested parcels (i.e., between 10 and 1000 acres in size), also known as family forest owners, small woodland owners, or nonindustrial private forest owners, may be particularly affected. These owners manage over half of all forestland in the Northwoods (Butler and Ma, 2011) and are therefore highly exposed to the local impacts of climate change. They are also sensitive to these impacts due to their reliance on many of the goods and services that will be affected by climate change, such as timber, habitat and biodiversity, scenery, recreational opportunities, and land values (Butler and Ma, 2011; Pugh et al., 2009; Erickson et al., 2002; Potter-Witter, 2005). The management motivations and demographic characteristics of forest owners in the Northwoods are similar in many ways to those of the population of individual forest owners nationwide (Butler and Leatherberry, 2004; Butler and Ma, 2011; Pugh et al., 2009); therefore, insights from this study may have broader geographic relevance.

3.3. Data collection

Focus group interviews were used to gather data for this study.[1] Focus groups take advantage of group processes to provide insight into complex topics when individuals' opinions or attitudes are not fully formulated or when the area of concern relates to multifaceted behavior or motivation (Krueger and Casey, 2015). Focus group designs typically entail one set of three focus groups with each sample or, if samples are multidimensional, with each subsample (Krueger and Casey, 2015). The salient dimensions were not mutually exclusive in this study; therefore, the sample could not be divided neatly into subsamples. Instead, nine focus groups were conducted in sites across the study area to capture variation on three overlapping dimensions that are arguably important to landowners' management responses: socio-political conditions, biophysical conditions that create opportunities and constraints for management, and exposure to local forest stressors that can arguably be linked to global climate change (Table 1). Focus groups were also held across the three states in the study area (Minnesota, Wisconsin, and Michigan); in areas with each of the major forest types (i.e., maple beech birch, jack-red-white pine, spruce-fir, oak-hickory, and aspen-birch); and in areas where, according to scientific literature, forests had

[1] The research design was reviewed and determined "exempt" by the University of Michigan Health Sciences and Behavioral Sciences Institutional Review Board (IRB-HSBS) due to its low risk to participants.

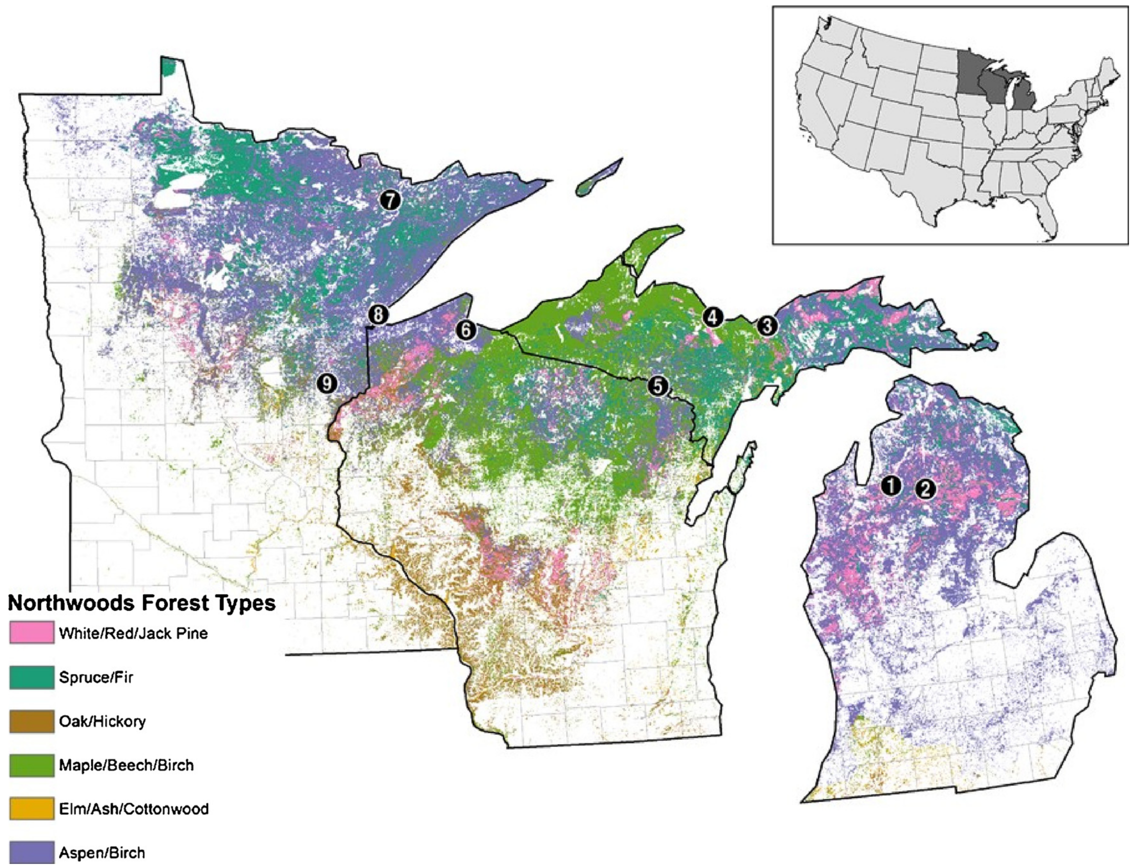

Fig. 1. Study area and approximate locations of focus groups: (1) Kalkaska, (2) Crawford, (3) Munising, (4) Marquette, (5) Florence, (6) Ashland, (7) Ely, (8) Boulder Lake, and (9) Sandstone.

experienced and were projected to experience major insect and disease incursions, storms, wildfires, and changes in temperature and precipitation patterns (i.e., forest stressors) (Janowiak et al., 2014a; Handler et al., 2014a, b). Two other criteria for selecting the sites were that substantial proportions of land in the area were in individual private ownership (as opposed to federal, state, or corporate ownership) and a natural resource or community organization was willing to serve as a local partner and host. The sufficiency of the sample size was confirmed through saturation, the process in which new themes dramatically diminish despite each new observation (Krueger and Casey, 2015; Patton, 2002).

The population of interest was individual forestland owners with enough land to manage for purposes other than maintaining a home site (i.e., at least 20 acres in size) and who actively manage their forestland. Owners were recruited with help from natural resource professionals who work in local branches of public landowner assistance agencies (e.g., state departments of natural resources, conservation districts, and Cooperative Extension Service offices). In other words, participants composed a purposive sample of landowners who interact with experts and are therefore likely to be actively engaged in forest management. A total of 85 such owners participated in the focus groups, with an average of 10 participants in each group, although one group included four participants and another group included 16 participants. Most of these individuals represented households and extended families; in a few cases, participants were members of the same household or extended family (e.g., husband and wife, parent and adult child).

The focus group interview questionnaire consisted of open-ended questions in four sections: (1) changes owners had observed in their forests and how they had been impacted; (2) management practices owners undertook to respond to the changes and factors in their responses; (3) ways owners changed their management approaches in response to changes (i.e., strategies); and (4) views on projected future changes, plausible management responses, and potential factors in responses. The terms climate change and global warming were not used in any of the interview questions due to the controversial nature of the terms, although landowners brought them up anyway. A trained group facilitator conducted the focus group interviews, which lasted approximately three hours each. This paper focuses on the changes owners made in their management behavior (i.e., the data from sections two and three of the interview instrument).

3.4. Data analysis

The focus group interview data were analyzed with qualitative content analysis (Schreier, 2014) and grounded theory (Charmaz, 2001; Glaser and Strauss, 1999) according to a four step process. In the first step, preliminary analytical memos (Miles et al., 2014) were developed after each focus group to summarize the groups' responses to the interview questions, identify emergent categories of practices and strategies with which to characterize landowners' behavioral adjustments, characterize responses in terms of predefined categories of adaptation behavior (i.e., purposefulness, timing, scope, and goals), and describe any evidence of responses that exhibited characteristics of adaptation versus coping.

In the second step, the interview data were segmented in two cycles with codes assigned to quotations that provided insight into the interview and research questions. In a first cycle of coding, emergent categorical codes (i.e., those identified through grounded theory) were assigned to quotations that conveyed information about past management responses (i.e., practices and strategies). Categorical codes are typically used in the first cycles of coding to segment or distill data into a smaller number of similar descriptive groupings (Miles et al., 2014). Codes

Table 1
Focus group sites and area attributes.

	Site Name	Geography	Forest Types	Forest stressors
1	Kalkaska, Kalkaska Co., MI	Northern Lower Peninsula, MI	Maple, beech, birch; pine; oak	Minor wildfire events; moderate beech bark disease, emerald ash borer, and oak wilt infestations
2	Grayling, Crawford Co., MI	Central Lower Peninsula, MI	Pine; oak	Minor wildfire events; moderate drought; moderate wind storms; moderate oak wilt and chestnut borer infestations
3	Munising, Alger Co., MI	Central Upper Peninsula, MI	Maple, beech, birch; aspen	Severe wildfire events; severe rainfall and flooding events; severe beech bark disease, emerald ash borer, spruce budworm, and chestnut borer infestations
4	Marquette, Marquette Co., MI	Central Upper Peninsula, MI	Spruce, fir; oak	Minor wildfire events; severe rain and windstorm events; severe spruce budworm and emerald ash borer infestations
5	Florence, Florence Co., WI	Northeast WI	Aspen; spruce, fir; maple, birch; pine	Minor wildfire events; severe wind events; severe beech bark disease and oak wilt infestations
6	Ashland, Ashland/Bayfield Co., WI	Northwest WI	Aspen; oak; pine; maple	Minor wildfire events; severe drought events; severe wind and flooding events; moderate chestnut borer infestations
7	Ely, Saint Louis Co., MN	Northeast MN	Aspen; spruce, fir; maple; pine	Severe wildfire events; severe wind events; severe spruce budworm, pine weevil, and tent caterpillar infestations
8	Duluth, Saint Louis Co., MN	Northeast MN	Birch; oak; maple; pine; fir; ash	Minor wildfire events; moderate wind events; moderate spruce budworm and white pine blister rust infestations
9	Sandstone, Pine Co., MN	Eastern MN	Maple, beech, birch; aspen	Minor wildfire events; moderate wind events; moderate spruce budworm infestations

were also assigned to quotations about the owners' experiences of forest stressors, factors in their response, and views on any potential responses to future stressors, although those last findings are not the focus of this paper. After the first three focus group interviews, the research team compared and aligned their interpretations of codes and coding approaches to ensure inter-coder reliability. In a second cycle of coding, I distilled the categorical codes and reapplied them alongside analytical codes to identify key emergent responses (i.e., specific groupings of practices and strategies), responses that exhibited predefined categories of adaptation behavior (i.e., purposefulness, timing, scope, and goals), and responses that exhibited elements of adaptation versus coping. I then grouped the practices according to the actions they entailed (e.g., harvesting, planting), and I grouped the strategies according to the type of mechanism that governed the relationship between the practices and the theoretical goal of adaptation: reducing adverse impacts over the long term while continuing to derive value from forests despite new environmental conditions.

In the third step, I developed analytical memos for each broad category of analytical code (e.g., salient forest changes, practices, strategies, response attributes, adaptation versus coping) to describe patterns and relationships in the landowner responses and the ways in which their responses were consistent with adaptation typologies. In the fourth and final step, I distilled data into matrix displays (e.g., Tables 2 and 3) to illustrate the relationships between codes (Miles et al., 2014). NVivo data analysis software was used to manage the data and metadata throughout the analysis process (QSR International Pty Ltd, 2012).

4. Results

4.1. How have landowners adjusted their forest management behaviors?

The landowners in the study responded to the changes in their forests, or forest stressors, by undertaking 13 primary management practices, grouped into four categories based on the broad types of activities they entailed: harvesting, planting, engineering, and planning (Table 2). They undertook these practices as part of seven different strategies, grouped into two categories: strategies for managing ecological conditions and processes (i.e., nature) and strategies for managing risk (Table 2). The forest stressors that they were responding to included aberrant weather patterns, severe storms, pest and disease outbreaks, and shifts in plant and animal species composition—and, to some extent, wildfires and invasive plant incursions. In every focus group, landowners attributed the changes they experienced in their forests at least in part to "global warming" or "climate change."

4.1.1. Harvesting practices

Landowners undertook four practices that involved the removal of vegetation. They cut stands of trees that had already succumbed to stressors such as pest and diseases (salvage harvest) and culled trees that they expected to succumb to stressors in the future (anticipatory cull). A landowner in the Florence area described his rationale for anticipatory culling: "*We want to get ours logged now and not wait because we'll have nothing but dead trees pretty soon if this keeps up and then what do we do with them?*" Landowners also removed vegetation around individual trees, stands, and structures to buffer them from pests and diseases or wildfires that might move across the landscape (buffering) and thinned stands of trees to reduce stress from drought, damage from storm events, and spread of pests and diseases and wildfires (mitigation thinning).

4.1.2. Planting practices

Landowners undertook two planting practices. They cultivated a wider range of tree species to increase the chances that some trees would weather stress (cultivate diverse species), and they cultivated species that they expected to be more robust under future conditions

Table 2
Practices and strategies that owners reported undertaking most frequently to respond to forest stressors (i.e., were discussed in at least five of the nine focus groups) are listed as row headers and column headers. Integers in bold indicate the total number of focus groups in which a practice or strategy was reported. Integers in italics indicate the number of focus groups in which a practice was reported explicitly as part of a strategy. The absence of an integer at the intersection of a practice row and strategy column indicates that landowners did not explicitly report following the strategy to implement a practice.

Practices			Strategies						
			Nature management strategies				Risk management strategies		
			Imitate nature	Innovate nature	Control nature	Let nature be	Reduce risk	Spread risk	Cut losses
		Number of focus groups in which practice or strategy was discussed							
Harvesting	Salvage harvest	**8**			*4*				*5*
	Anticipatory cull	**6**		*1*	*2*		*5*		
	Buffer	**5**	*2*		*2*		*2*		
	Mitigation thin	**8**	*2*		*2*		*2*	*1*	
Planting	Cultivate diverse species	**8**	*2*	*4*				*6*	
	Cultivate robust species	**6**	*4*	*5*			*2*	*2*	
Engineering	Chemically treat	**5**							
	Install structures	**5**							
Planning	Learn	**8**							
	Develop plans	**8**				*4*	*3*	*1*	
	Monitor	**8**				*3*			
	Enroll	**6**					*2*		
	Alter seasonality	**6**					*2*		
Total			**6**	**7**	**6**	**5**	**6**	**8**	**5**

due to their moisture or drought tolerance (cultivate robust species), including species from other geographic areas that they expected would do well and be less vulnerable to future stressors.

4.1.3. Engineering practices

Landowners used two practices that involved engineering. They built stream culverts, levees, irrigation devices, and other structures to protect trees and soils against flooding, drought, and storm events (install structures) and applied herbicides and pesticides to protect trees from pests and diseases and prevent spread (chemically treat).

4.1.4. Planning practices

Landowners undertook five planning practices. They educated themselves about forest management options, primarily through consultation with natural resource professionals (learn); enrolled in government programs to obtain funding for their management efforts (enroll); and developed forest management plans, often as part of these programs (develop plans). Landowners also monitored their forests for signs of stress (monitor); as a landowner in the Munising area described, "*Another thing I do differently now is constant monitoring.. . . Every time I am walking my river on my property, I am looking at the hemlock trees for any signs of hemlock woolly algid decline or infestation.*" Finally, landowners changed the seasonality of their operations to prevent spreading pests and diseases in warm wet spring weather and damaging soils and roots during winter thaws (alter seasonality). A landowner in the Kalkaska area described this practice: "*Putting on our climate lens, now we do not cut oak between April 15 and July 15 because we know that is the prime time for the oak wilt spread.*"

4.1.5. Strategies for managing the human-nature relationship

Landowners described four forest management strategies that reflected distinct ways of managing ecological conditions and processes (i.e., nature). These included imitating nature, innovating upon nature, taking control of nature, and letting nature be (Table 2). Landowners imitated nature when they cultivated diverse and robust species in their forests that would fare well under future conditions. "*If I walk around and look at all the young trees in the forest, they are all pine trees and virtually none of them are hardwoods; that is what wants to be here, so might as well go with the flow,*" explained a landowner in the Crawford area. Landowners imitated nature by creating gaps—as small windstorms might do—to buffer stands from pests and diseases and wildfires and by thinning individual trees from stands to reduce competition and prevent the spread of pests and diseases and wildfires (individual tree mortality is a part of stand development).

Landowners innovated upon nature by planting tree species from other areas where conditions were similar to what they expected in the future for their area in order to create robustness that would not have occurred on its own. A landowner near Ashland explained: "*The species that are more prevalent in central Wisconsin; I think those ones are moving north. . . white oak—which traditionally is not found here—I think we have a crack at it now with climate change.*" Landowners also planted new species to diversify their forests. A landowner in the Crawford area, for

Table 3
Classification of reported forest management strategies (in columns) in terms of adaptation behavior attributes (in rows). An "x" indicates that a reported strategy is consistent with an adaptation behavior attribute.

Practices		Strategies						
		Nature management strategies				Risk management strategies		
		Imitate nature	Innovate nature	Control nature	Let nature be	Reduce risk	Spread risk	Cut losses
Purposefulness	Autonomous	x			x		x	x
	Planned		x	x		x		
Timing	Reactive							x
	Proactive	x	x	x		x	x	
Scope	Incremental	x	x	x		x	x	x
	Transformational							
Goals	Resistance					x		
	Resilience	x					x	
	Transition		x	x	x			x

example, planted fruit trees and nut trees in hopes that these non-native hybridized tree species might do well in the future, when native species would not. Installing structures and applying chemicals could be viewed as practices that innovate upon nature, although landowners did not articulate this connection.

Landowners took control of nature by responding early and aggressively to forest stressors. Despite original intentions to manage passively, by treating their forests as self-regulating systems, some landowners said they felt compelled to play a more active role. "*I always thought doing nothing was the easiest way to go. I tried that and it did not seem to work*," explained a landowner in the Crawford area, echoing what landowners said in the Marquette, Munising, and Florence focus groups. "*With diseases and pests, if you are doing nothing you are resisting change*," said a landowner in the Munising area. Salvage harvesting, anticipatory culling, buffering, and mitigation thinning were other practices that they reported undertaking when they described taking control of nature.

Some landowners let nature be, allowing it to follow its course. *"We're going to let nature point the way, we're going with nature, it is too hard to fight it,"* said a landowner from the Crawford area about his decision to take a more passive approach. The practices that these landowners undertook were limited to developing long-term management plans and monitoring. Such landowners put management decisions into perspective by considering the far past and far future, which relieved some of the pressure they felt to make decisions under uncertainty. A landowner in the Munising area explained: "*Know that the land is resilient, and that it will rebound even if humans dramatically alter it. Ten thousand years ago this was a glacial outwash plain, so whatever happens, the land can rebound from it*."

4.1.6. Risk management strategies

Landowners described three forest management strategies that reflected distinct ways of managing the probability and severity of adverse events (i.e., risk): reducing risk, spreading risk, and cutting losses. Landowners said they attempted to reduce the risk of wildfires and pests and diseases through mitigation thinning, creating buffers, and especially anticipatory culling. A landowner in the Ashland area described his family's decision to harvest their pine trees earlier than planned in anticipation of future stressors: *"[We're] speeding up the red pine harvest rather than letting it go the full rotation cycle because with letting it go the full term the value gained is not justified by the risk of leaving it because of wildfires and other natural disasters."* A different landowner in the Ashland area explained his family's decision to remove ash trees before they became infested: *"We're removing ash with anticipation of the emerald ash borer getting here."* Some landowners said they reduced risk through planning. One landowner in the Crawford area explained how the need to reduce risk motivated her to enroll in a cost-share program and develop a forest management plan: *"My thought on getting into the forest program was. . . [that] I will be given the information that I needed and hopefully will be able to prevent things that may occur, because I know it is on the doorstep."* Landowners also reduced risk by changing the seasonality of forest operations. For example, not harvesting in spring when moisture and warmth is most conducive to spreading diseases or harvesting only in deep winter to ensure firm ground for heavy equipment in order to avoid damaging roots and soils. Landowners also applied pesticides to reduce the risk of pest and disease infestations and installed culverts and levees to reduce the risk of flood and drought damage, although they did not explicitly describe these practices in terms of risk reduction.

Landowners spread risk primarily by planting diverse species and species they thought would be more robust in the future. A landowner in Ely explained, "*We do not know what is going to come up next and hit a particular species. We want a variety in there to help with that*." A landowner in the Crawford area explained: "*There is no sense planting 1000 of one kind of tree if they are not going to take off. So I plant 25–30 trees of a different type and if I see that species is going to do well. . . I do a different one each year*." One landowner in the Crawford area said he spread risk by developing redundant plans; he now approaches forest management by "*having a back-up plan to the back-up plan*."

Landowners cut their losses by salvage harvesting stands of trees that had succumbed to pests and diseases or storms to garner any remaining market value. "*You gotta do something,*" explained a landowner in the Munising area*, "I look at trees as an asset. What is the best way to manage your asset? Get the most that you can get for it*." Landowners also cut losses by choosing not to implement practices. A landowner in the Crawford area said: *"I'm not doing anything to irrigate in response to drought because it is too expensive. I'm just losing trees and replanting with drought-adapted species."*

4.2. What key attributes of adaptation behavior are exhibited in owner responses?

The strategies that landowners undertook to respond to stressors in their forests demonstrated key attributes of adaptation behavior from published typologies (e.g., (Fankhauser et al., 1999; Smit et al., 2000; Birkmann, 2011; Burton et al., 1993; Klein, 2003), specifically purposefulness, timing, and scope, as well as goals (Table 3).

4.2.1. Purposefulness: Autonomous versus planned

The landowners engaged in ongoing implementation of existing forest management knowledge and techniques when they imitated nature and spread risk (e.g., by planting diverse and robust species) and when they cut their losses (e.g., through salvage harvesting). In this way, they engaged in autonomous adaptation. However, in their efforts to innovate upon nature (e.g., by planting diverse and robust species) and take control of nature and reduce risk (e.g., through anticipatory culling), landowners created and applied new knowledge and techniques, exhibiting planned adaptation.

4.2.2. Timing: reactive versus proactive

Landowners' efforts to cut losses constituted ex-post efforts to regain stability, that is, reactive adaptation; they conducted salvage harvests after their forests had been adversely impacted by pests and diseases, storms, and drought. Yet through efforts to imitate and innovate upon nature (e.g., planting diverse and robust species) and take control of nature (e.g., through salvage harvesting, anticipatory culling, buffering, and thinning), they reoriented their practices to reduce future damage, risk, and vulnerability, that is, proactive adaptation. As one Crawford area landowner said about his rationale for culling an oak species from his forest in anticipation of future infestation: "*If this disease does not get it, the other disease will. We have only seen one outbreak of oak wilt but we're thinking we will be seeing more. That is why I am trying to be proactive*."

4.2.3. Scope: incremental versus transformational

Through all their practices and strategies, landowners made relatively small changes to avoid disruptions and continue pursuing the same objectives (e.g., managing forestland to derive monetary, aesthetic, recreational, and other values). Despite the increasing extent, frequency, and severity of pest and disease infestations and storms and steadily rising temperatures across the hundreds and thousands of acres of forestlands that comprise the Northwoods, landowners undertook management practices on the order of tens of acres rather than on larger spatial extents. Moreover, they did not report making fundamental changes to the way forests were managed in the region as a whole or to the economic and social systems that governed management of the region's forests. These responses suggest that landowners pursued incremental rather than transformational adaptation. Nevertheless, landowners recognized the importance of transformational responses (although recognizing the importance of something does not predict behavior). For example, landowners in six of the focus groups (Ashland, Boulder Lake, Ely, Munising, Marquette, and

Sandstone) suggested that coordinating their forest management activities across property boundaries might enable them to make changes in forest conditions on large spatial extents, thereby increasing the efficiency and effectiveness of management efforts. Implementing the same practices on multiple adjacent parcels could prevent the spread of potential pests and diseases or wildfires, they proposed. They also suggested that by pooling resources they might be able to improve their ability to operate in warmer, wetter conditions, for example, by creating a single robust network of all-weather access roads. Landowners also proposed that formal forestry cooperatives might enable them to increase the economy of scale and, thus, the viability of their forestry operations. These types of responses, if implemented, would be transformational because they would require new types of social organization. Another transformational strategy landowners proposed was incentivizing management with market-based policy tools. Landowners in the Ashland, Crawford, Florence, and Kalkaska focus groups called for new operating technologies, processing facilities, and markets to support harvesting and planting, especially during warmer and wetter conditions.

4.2.4. Goals: resistance versus resilience versus transition

The landowners in this study pursued strategies that reflected the three major goals of adaptation identified in forestry frameworks: resistance, resilience, and transition (Table 3). By engaging in response strategies—culling, buffering, and thinning—to reduce the risk of trees succumbing to pests and diseases, storms, droughts, and wildfire events, landowners aimed to resist stressors that may adversely affect their forests. By planting diverse and robust species as strategies for imitating nature and spreading risk, landowners aimed to create forest conditions that could undergo and recover from change and still function as Northwoods forest systems (i.e., resilience). By planting new species to innovate upon nature; aggressively culling, buffering, and thinning—to control nature and salvage logging to cut their losses—landowners enabled change (i.e., transition).

4.3. How do landowner responses constitute adaptation as opposed to coping?

Some of the landowners' responses arguably can be considered adaptation rather than coping because they were aimed at moderating or avoiding harm over the long term, as opposed to temporarily mitigating near-term shocks and stresses. Some of the practices they undertook require long time horizons, for example, planting trees that they may never live to see harvested and thinning to mitigate the slow tide of pests and diseases. The adjustment of strategies in order to manage ecosystem conditions and processes (nature) and risk can also be long-term endeavors. Moreover, landowners undertook these efforts in ways that were, to some extent, planned and proactive. Through practices such as anticipatory cutting, thinning to mitigate risk, learning, altering the seasonality of forestry operations, monitoring, and developing plans, landowners acted in anticipation of future change. The strategies of spreading risk and mitigating risk were also oriented around future change. Landowner responses to local forest stressors entailed anticipatory and intentional actions to address change through the use of information about forest stressors (i.e., lay knowledge derived from experience, as well as expert knowledge from natural resource professionals) to evaluate the future suitability of their forest practices, as well as the policies and infrastructure that affect them.

5. Discussion

This study's findings contribute to scientific understanding of behavioral adaptation to climate change. They expand on a small but growing body of empirical research on individual adaptation to local stressors that can be linked to global climate change, including a limited number of studies on individual adaptation in the context of forests. In particular, this study advances approaches to investigating adaptation behavior by applying a conceptually rigorous framework to analyze empirical data about forest owner responses to local stressors that could arguably be attributed to global climate change. It also advances our understanding of adaptation behavior by demonstrating how adaptation can be distinguished from coping on the basis of emergent and predetermined attributes.

The finding that forestland owners undertook planned adaptation is notable, not only because it offers rare empirical evidence of this behavioral attribute among individuals, but also because it provides guidance for the interpretation of responses in other studies. At the time of this paper, it appeared that only five other studies of climate change adaptation at the individual level distinguished between strategies on the basis of adaptation behavior attributes (van Gameren and Zaccai, 2015; Zheng and Dallimer, 2016; Grothmann and Patt, 2005, Raymond and Robinson, 2013, Wheeler et al., 2013), only one of which was in the context of forests: van Gameren and Zaccai (2015). The findings from the present study are consistent with that study's characterization of responses that involve the experimentation with new species and stand structures and the seeking out information about new forestry approaches as "planned adaptation measures," as well as its characterization of responses that involve the cultivation of diverse mixes of species as "autonomous adaptation measures" (van Gameren and Zaccai, 2015).

The finding that forest owners undertook proactive approaches is also notable given that much research on adaptation at the individual level describes reactive approaches. Indeed, this study suggests that many of the practices that have been documented among landowners in response to stressors in temperate forests—replacing vulnerable species with stress-tolerant species, adjusting stand structure through thinning, increasing spacing of seedlings to reduce susceptibility to wind storms and drought, and purchasing insurance to mitigate potential losses (Eriksson, 2014; Sousa-Silva et al., 2016; van Gameren and Zaccai, 2015; Blennow and Persson, 2009)—could also be considered proactive response strategies, even though studies have not framed them as such. Moreover, some proactive responses (e.g., planting diverse species) are meant to prevent the need for reactive approaches (e.g., salvage harvest), that is, to serve as substitutes for reactive approaches (Fankhauser et al., 1999).

The finding that owners had not undertaken transformational responses is not surprising. Few to no studies have documented cases of individuals responding to climate change impacts by engaging in truly new behaviors at large scales that would fundamentally change the broader biophysical, social, or economic system. In fact, in a study that documented nonadaptation among individual forest owners in the US Pacific Northwest region, landowners pointed out that changing management practices in the near term to respond to potential future climate scenarios was at odds with their time scales of forest management, which range from a few years to a few decades (Grotta et al., 2013). Moreover, transformation may be inherently difficult to document through cross-sectional studies, as some people's transformational responses may have removed them from small-scale forestry and thus, the sampling frame for this study. Transformation may also be uncommon within the demographic of typical forest landowners: people approaching or of retirement age (Butler and Ma, 2011), who may be less amenable to dramatic change (Quinn and Adger, 2011). Nevertheless, the landowners in this study saw a need for transformational responses. The strategies they suggested—cooperating with neighbors to increase the spatial scale and efficiency of management (documented among forest landowners in other studies, although not explicitly in response to climate change) (Fischer et al., 2018; Fischer and Charnley, 2012) and developing new markets for byproducts of management—entail substantial changes to social and economic systems and would likely require information, resources, and power on the part of institutions, not just individuals. Although this study was an investigation of adaptation at the individual level, the participants proposed responses on

longer time horizons, larger spatial extents, and higher levels of social organization than are typical of individual behavior. One explanation for this may be the capital-intensive nature of forest management. Forestry is an enterprise in which decisions (e.g., planting a tree that will not reach a marketable size for decades) can be very difficult under conditions of uncertainty and are not easily reversible (Mendelsohn, 2000). In the context of forests, individuals may not be capable of making many of the behavioral adjustments that are needed for adaptation. Rather, adaptation may hinge on changes at higher levels of social organization (e.g., institutions) that can draw on information and resources that are typically held collectively. Therefore, empirical data about individual behavioral intentions and motivations, as well as past behaviors, may be important.

This study also expands on empirical and theoretical efforts to differentiate adaptation and coping (e.g., Osbahr et al. (2008) and Smit and Wandel (2006)). The planned and proactive nature of the landowner responses are consistent with adaptation, rather than coping, because they aimed to moderate or avoid harm over the long term, as opposed to temporarily mitigating near-term shocks and stresses (Smit et al., 1999; Denevan, 1983; Adger et al., 2005; Bassett and Fogelman, 2013; Burton et al., 1993). However, behaviors with these attributes are not typical of individuals (Gifford, 2011; Reser and Swim, 2011; Swim et al., 2009). Again, the nature of forests may help explain this. Because forests require management on multi-decadal time horizons, many seemingly short-term responses (e.g., salvage harvesting) may actually serve as steps within broader, longer-term responses (e.g., shifting to a more diverse and robust species composition). In the Northwoods, the timeframe of the landowner responses reflects the timeframes of forest stressors, which are gradual, for the most part. This observation is consistent with other literature that suggests that rapid onset short-term disturbances tend to trigger temporary reactive responses, whereas longer-term disturbances result in long-term behavioral change (Osbahr et al., 2008). Thus, in the context of forests, adaptation may be a more suitable response than coping. Recognizing that the nature of a response is, to some extent, a function of the nature of a stressor is important because it can encourage program evaluators to exercise discretion when attributing adaptation solely to adaptive capacity or adaptation policy.

Although the findings from this study provide insight on how to evaluate whether and how adaptation occurs at the individual level, it is important to keep in mind that determining whether adaptation has occurred and distinguishing adaptation from coping and other types of responses ultimately depends on the scales at which the behaviors are considered (Adger et al., 2005). A behavior that lowers one's suitability to the environment in the short term may nevertheless prove to be adaptive over longer periods of time. For example, relocating outside the inundation zone of the future coastal floods expected under sea level rise may have immediate adverse impacts on financial and psychological wellbeing, but may protect life and property in the future, enabling people to live in coastal environments (King et al., 2014). In the context of wildfire-prone temperate forests, landowners who periodically reduce flammable vegetation may incur modest costs on a yearly basis, but could be spared a catastrophic loss over time (Fischer et al., 2016). Similarly, a behavior that improves an individual's suitability to the environment at a local level may have adverse consequences regionally. For example, by suppressing wildfires on their own properties and allowing vegetation to accumulate, landowners might increase the chance of catastrophic fires in the future that could damage wider areas (Fischer et al., 2016).

Hence, a limitation of this study is that, as a cross-sectional study, it was not designed to evaluate improvements in suitability to the environment over time, which would indicate adaptation in the strict sense (Sober, 1993; Smit and Wandel, 2006). Likewise, the study was not designed to assess such phenomena on large spatial scales: landowners in the focus groups were asked to respond in reference to forest stressors on or near their properties. Another limitation of the study is one that is inherent to focus-group-based research. Given that the unit of observation and analysis was the group, I was not able to discern differences between individual responses and group responses. It is also possible that some of the individual landowners may not have been responding to change at all, thereby exhibiting nonadaptation. Indeed, in almost every group, landowners mentioned the possibility of "throwing in the towel" or "throwing up their hands," if they were to experience a disturbance event that caused major losses, thus indicating potential for nonadaptation.

This study provides insight into the use of typologies for evaluating whether and how adaptation occurs at the individual level. By characterizing the landowners' tactics and strategies with both emergent (a posteriori) as well as predetermined (a priori) categories, I was able to evaluate how landowners exhibited both place-specific and universal adaptation behaviors and how their responses differed from coping. By incorporating the goals of a particular behavior into the overall characterization of behavioral adjustments, this study helps distinguish between adaptation and coping on the basis of whether behaviors aim to resist change, increase resilience to change, or facilitate change (transition). Given that individuals may not be capable of realizing all intended behavioral changes, information about the landowners' goals for responding to forest stressors provides additional insight into how their responses could constitute adaptation if they were able to successfully implement their practices and strategies. It is especially important to include the goals for adaptation in typologies, given that the evaluation of improved suitability—an indicator of successful adaptation in the strict sense (Fankhauser et al., 1999)—is a challenge in the absence of longitudinal data (Smit and Pilifosova 2001). Even if suitability has not demonstrably improved in the near term, it can be assumed that transitioning to management practices that address new conditions and stressors will at least increase the chances that landowners will be able to moderate or reduce adverse effects of climate change in the future.

This study identifies several potentially fruitful areas for future research. First, investigating the implications of individual responses to climate change that fall at different points along the dimensions of purposefulness, timing, scope, and goals would be beneficial. For example, responses that are planned and proactive, despite being incremental, and that constitute efforts to transition to new environmental conditions may indicate underlying conditions under which individuals are willing undertake transformational adaptation. Such efforts could disproportionately benefit others (i.e., through joint adaptation or private adaptation for public benefit) (Mendelsohn, 2000; Tompkins and Eakin, 2012) and therefore would be societally desirable. Second, considering the bio-geophysical context of stimulus and response would be useful. Adaptation may be a more rational response than coping in certain contexts, such as forests, where long-lived and spatially inter dependent phenomena require proactive, planned management responses. Understanding the role of human-environment interdependencies in adaptation could help researchers decide to what degree adaptation responses are attributable to policy, as opposed to other variables such as culture, individual capacity, or social capital. Third, a more rigorous approach to characterizing behavioral responses to climate change according to purposefulness, timing, scope, and goals, and distinguishing between adaptation and coping, will yield clearer and more coherent dependent variables that future studies can model as a function of explanatory frameworks, most commonly consisting of cognitive and social variables, e.g., (Ajzen, 1991; Grothmann and Patt, 2005; Rogers, 1975; Lindell and Perry, 2012). In fact, the next step for this research is to model forest landowner responses to climate change as a function of landowners' subjective appraisals of risk and capacity to respond, social norms and other peer effects on behavior, access to resources (i.e., assets), and qualities of the changes themselves (pace, frequency, severity, and interdependence) (Hamilton et al., 2018).

6. Conclusion

The difficulty of assessing whether and how adaptation occurs is an ongoing constraint to designing policies and programs and evaluating their effectiveness (Burton and May 2004). This study suggests that applying a conceptually rigorous analytical framework to empirical data about target group behavioral responses to climate change could provide important information about whether and how people are adapting. By characterizing people's responses to local stressors using emergent categories of forest management behavior and predetermined categories of adaptation behavior from published typologies, I was able to evaluate how adaptation was occurring among individual forestland owners in the Northwoods, USA, and whether their responses exhibited elements of adaptation versus coping. I found that the landowners responded to the stressors affecting their forests with strategies that were both autonomous and planned; more proactive than reactive; and incremental rather than transformational, although they recognized the need for transformational response. Through these strategies, and the practices that composed them, the landowners sought to resist and be resilient to changing conditions, as well as to transition to new conditions. These responses can aptly be described as adaptation because they aimed to moderate or avoid harm over the long term, as opposed to temporarily mitigating near-term shocks and stresses. This study provides an example of how to characterize people's responses to climate change systematically and asserts the importance of distinguishing between adaptation and coping. Such an approach, if widely applied, could improve methods for evaluating adaptation policy outcomes and societal progress toward learning to live with, and thrive, despite change.

Funding sources

This work was supported by the USDA National Institute of Food and Agriculture McIntire-Stennis Program [1011135], USDA Forest Service Northern Research Station, University of Michigan Energy Institute, and University of Michigan Graham Sustainability Institute.

Acknowledgements

I thank Michal Russo and Garrett Powers for helping plan, conduct, transcribe, and summarize the focus group interviews. University of Michigan Doris Duke Conservation Scholars Makayla Marshal and Brandon Arbuckle also helped transcribe and summarize the focus groups. Mike Reichenbach, Mark Randolph, Matt Watkeys, Diane Bomer, Valerie Damstra, Gloria Erickson, Nicole Butler, and Tyler Wood hosted and helped recruit participants in the focus groups. Mike Reichenbach, Mike Smalligan, Kris Tiles, Stephanie Snyder, and Stephen Handler provided advice during the planning stages. I thank Neil Adger, Matt Hamilton, Michal Russo, and Aniseh Bro and two anonymous reviewers for providing comments on an earlier version of this manuscript.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gloenvcha.2018.10.011.

References

Adger, W.N., Arnell, N.W., Tompkins, E.L., 2005. Successful adaptation to climate change across scales. Global Environ. Change 15, 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005.

Adger, W.N., Dessai, S., Goulden, M., Hulme, M., Lorenzoni, I., Nelson, D., Naess, L., Wolf, J., Wreford, A., 2009. Are there social limits to adaptation to climate change? Clim. Change 93, 335–354. https://doi.org/10.1007/s10584-008-9520-z.

Ajzen, I., 1991. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50, 179–211.

Allen, C.D., Macalady, A.K., Chenchouni, H., Bachelet, D., Mcdowell, N., Vennetier, M., Kitzberger, T., Rigling, A., Breshears, D.D., Hogg, E.H., Gonzalez, P., Fensham, R., Zhang, Z., Castro, J., Demidova, N., Lim, J.-H., Allard, G., Running, S.W., Semerci, A., Cobb, N., 2010. A global overview of drought and heat-induced tree mortality reveals emerging climate change risks for forests. For. Ecol. Manage. 259, 660–684.

Barbier, B., Yacouba, H., Karambiri, H., Zoromé, M., Somé, B., 2009. Human vulnerability to climate variability in the Sahel: farmers' adaptation strategies in Northern Burkina Faso. Environ. Manage. 43, 790–803. https://doi.org/10.1007/s00267-008-9237-9.

Barnett, J., O'neill, S., 2010. Maladaptation. Global Environ. Change 20, 211–213. https://doi.org/10.1016/j.gloenvcha.2009.11.004.

Bassett, T.J., Fogelman, C., 2013. Déjà vu or something new? The adaptation concept in the climate change literature. Geoforum 48, 42–53. https://doi.org/10.1016/j.geoforum.2013.04.010.

Berrang-Ford, L., Ford, J.D., Paterson, J., 2011. Are we adapting to climate change? Global Environ. Change 21, 25–33. https://doi.org/10.1016/j.gloenvcha.2010.09.012.

Birkmann, J., 2011. First- and second-order adaptation to natural hazards and extreme events in the context of climate change. Nat. Hazards 58, 811–840. https://doi.org/10.1007/s11069-011-9806-8.

Blaikie, P., Cannon, T., Davis, I., Wisner, B., 1994. At Risk: Natural Hazards, People's Vulnerability, and Disasters. Routledge, London.

Blennow, K., 2012. Adaptation of forest management to climate change among private individual forest owners in Sweden. For. Policy Econ. 24, 41–47. https://doi.org/10.1016/j.forpol.2011.04.005.

Blennow, K., Persson, J., 2009. Climate change: motivation for taking measure to adapt. Global Environ. Change 19, 100–104. https://doi.org/10.1016/j.gloenvcha.2008.10.003.

Burton, I., Kates, R.W., White, G.F., 1993. The Environment as Hazard. Guilford press, New York.

Butler, B.J., Leatherberry, E.C., 2004. America's family forest owners. J. For. 102, 4–9.

Butler, B.J., Ma, Z., 2011. Family forest owner trends in the Northern United States. North. J. Appl. For. 28, 13–18.

Charmaz, K., 2001. Grounded theory. In: EMERSON, R.M. (Ed.), Contemporary Field Research: Perspectives and Formulations. Waveland Press, Inc., Prospect Heights, IL.

Cleland, D.T., Crow, T.R., Saunders, S.C., Dickmann, D.I., Maclean, A.L., Jordan, J.K., Watson, R.L., Sloan, A.M., Brosofske, K.D., 2004. Characterizing historical and modern fire regimes in Michigan (USA): a landscape ecosystem approach. Landscape Ecol. 19, 311–325. https://doi.org/10.1023/B:LAND.0000030437.29258.3c.

Denevan, W.M., 1983. Adaptation, variation, and cultural geography. Prof. Geogr. 35, 399–407. https://doi.org/10.1111/j.0033-0124.1983.00399.x.

Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., Yesuf, M., 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. Global Environ. Change 19, 248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002.

Duveneck, M.J., Scheller, R.M., 2016. Measuring and managing resistance and resilience under climate change in northern Great Lake forests (USA). Landscape Ecol. 31, 669–686. https://doi.org/10.1007/s10980-015-0273-6.

Erickson, D.L., Ryan, R.L., De Young, R., 2002. Woodlots in the rural landscape: landowner motivations and management attitudes in a Michigan (USA) case study. Landscape Urban Plann. 58, 101–112.

Eriksson, L., 2014. Risk perception and responses among private forest owners in Sweden. Small-Scale For. 13, 483–500. https://doi.org/10.1007/s11842-014-9266-6.

Fankhauser, S., Smith, J.B., Tol, R.S.J., 1999. Weathering climate change: some simple rules to guide adaptation decisions. Ecol. Econ. 30, 67–78. https://doi.org/10.1016/S0921-8009(98)00117-7.

Fazey, I., Gamarra, J.G.P., Fischer, J., Reed, M.S., Stringer, L.C., Christie, M., 2010. Adaptation strategies for reducing vulnerability to future environmental change. Front. Ecol. Environ. 8, 414–422. https://doi.org/10.1890/080215.

Field, C.B., Barros, V.R., Mach, K.J., Mastrandrea, M.D., Van Aalst, M., Adger, W.N., Arent, D.J., Barnett, J., Betts, R., Bilir, T.E., Carmin, J.B.J., Chadee, D.D., Challinor, A.J., Chatterjee, M., Cramer, W., Davidson, D.J., Estrada, Y.O., Gattuso, J.-P., Hoegh-Guldberg, Y.H.O., Huang, H.-Q., Insarov, G.E., Jones, R.N., Kovats, R.S., Romero, P., Lankao, J.N.L., Losada, I.J., Marengo, J.A., Mclean, R.F., Mearns, L.O., Mechler, R., Morton, J.F., Niang, I., Oki, T., Opondo, J.M.O.M., Poloczanska, E.S., Pörtner, H.-O., Redsteer, M.H., Reisinger, A., Revi, A., D.N, Schmidt, Solecki, M.R.S.W., Stone, D.A., Stone, J.M.R., Strzepek, K.M., Suarez, A.G., Tschakert, P., R, Valentini, Villamizar, S.V.A., Vincent, K.E., Warren, R., White, L.L., Wilbanks, T.J., Wong, P.P., And, G.W., Yohe, 2014. Technical summary. In: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., Maccracken, S., Mastrandrea, P.R., White, L.L. (Eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Fischer, A.P. Characterizing behavioral adaptation to climate change in temperate forest landscapes Landscape Urban Plann. https://doi.org/10.1016/j.landurbplan.2018.09.024 (in press).

Fischer, A.P., Charnley, S., 2012. Risk and cooperation: managing hazardous fuel in mixed ownership landscapes. Environ. Manage. 49, 1192–1207. https://doi.org/10.1007/s00267-012-9848-z.

Fischer, A.P., Spies, T.A., Steelman, T.A., Moseley, C., Johnson, B.R., Bailey, J.D., Ager, A.A., Bourgeron, P., Charnley, S., Collins, B.M., Kline, J.D., Leahy, J.E., Littell, J.S., Millington, J.D.A., Nielsen-Pincus, M., Olsen, C.S., Paveglio, T.B., Roos, Christopher I., Steen-Adams, M.M., Stevens, F.R., Vukomanovic, J., White, E.M., Bowman, D.M.J.S., 2016. Wildfire risk as a socioecological pathology. Front. Ecol. Environ. 14,

276–284. https://doi.org/10.1002/fee.1283.
Fischer, A.P., Klooster, A., Cirhigiri, L., 2018. Cross-boundary cooperation for landscape management: collective action and social exchange among individual private forest landowners. Landscape Urban Plann. https://doi.org/10.1016/j.landurbplan.2018.02.004.
Ford, J.D., Berrang-Ford, L., 2016. The 4Cs of adaptation tracking: consistency, comparability, comprehensiveness, coherency. Mitigat. Adapt. Strat. Global Change 21, 839–859. https://doi.org/10.1007/s11027-014-9627-7.
Ford, J.D., Berrang-Ford, L., Paterson, J., 2011. A systematic review of observed climate change adaptation in developed nations. Clim. Change 106, 327–336. https://doi.org/10.1007/s10584-011-0045-5.
Füssel, H.M., 2007. Adaptation planning for climate change: concepts, assessment approaches, and key lessons. Sustain. Sci. 2, 265–275. https://doi.org/10.1007/s11625-007-0032-y.
Gallopín, G.C., 2006. Linkages between vulnerability, resilience, and adaptive capacity. Global Environ. Change 16, 293–303. https://doi.org/10.1016/j.gloenvcha.2006.02.004.
Giddens, A., 1979. Central Problems in Social Theory. University of California Press, Berkeley.
Giddens, A., 1989. Constitution of Society: Outline of the Theory of Structuration. University of California Press, Berkeley.
Gifford, R., 2011. The dragons of inaction: psychological barriers that limit climate change mitigation and adaptation. Am. Psychol. 66, 290–302. https://doi.org/10.1037/a0023566.
Gifford, R., Kormos, C., Mcintyre, A., 2011. Behavioral dimensions of climate change: drivers, responses, barriers, and interventions. Wiley Interdiscip. Rev. Clim. Change 2, 801–827. https://doi.org/10.1002/wcc.143.
Glaser, B., Strauss, A., 1999. The Discovery of Grounded Theory: Strategies for Qualitative Research. Routledge, New York.
Grothmann, T., Patt, A., 2005. Adaptive capacity and human cognition: the process of individual adaptation to climate change. Global Environ. Change 15, 199–213.
Grotta, A.T., Creighton, J.H., Schnepf, C., Kantor, S., 2013. Family forest owners and climate change: understanding, attitudes, and educational needs. J. For. 111, 87–93. https://doi.org/10.1038/nclimate1542.
Haight, R.G., Cleland, D.T., Hammer, R.B., Radeloff, V.C., Rupp, T.S., 2004. Assessing fire risk in the wildland-urban interface. J. For. 102, 41–48.
Hamilton, M., Fischer, A.P., Guikema, S.D., Keppel-Aleks, G., 2018. Behavioral adaptation to climate change in wildfire-prone forests. Wiley Interdiscip. Rev. Clim. Change 9, e553. https://doi.org/10.1002/wcc.553.
Handler, S., Duveneck, M.J., Iverson, L., Peters, E., Scheller, R.M., Wythers, K.R., Brandt, L., Butler, P., Janowiak, M., Shannon, P.D., 2014a. Michigan forest ecosystem vulnerability assessment and synthesis: a report from the northwoods climate change response framework project. In: Handler, Secondary, S, Duveneck, M. J, Iverson, L, Peters, E, Scheller, R. M, Wythers, K. R, Brandt, L, Butler, P, Janowiak, Shannon, P.D. (Eds.), Secondary Michigan Forest Ecosystem Vulnerability Assessment and Synthesis: a Report from the Northwoods Climate Change Response Framework Project. GTR NRS-129. USDA Forest Service Northern Research Station.
Handler, S., Duveneck, M.J., Iverson, L., Peters, E., Scheller, R.M., Wythers, K.R., Brandt, L., Butler, P., Janowiak, M., Shannon, P.D., Swanston, C., Barrett, K., Kolka, R., Mcquiston, C., Palik, B., Reich, P.B., Turner, C., White, M., Adams, C., D'amato, A., Hagell, S., Johnson, P., Johnson, R., Larson, M., Matthews, S., Montgomery, R., Olson, S., Peters, M., Prasad, A., Rajala, J., Daley, J., Davenport, M., Emery, M.R., Fehringer, D., Hoving, C.L., Johnson, G., Johnson, L., Neitzel, D., Rissman, A., Rittenhouse, C., Ziel, R., 2014b. Minnesota Forest ecosystem vulnerability assessment and synthesis: a report from the northwoods climate change response framework project. secondary. In: Handler, S., Duveneck, M.J., Iverson, L., Peters, E., Scheller, R.M., Wythers, K.R., Brandt, L., Butler, P., Janowiak, M., Shannon, P.D., Swanston, C., Barrett, K., Kolka, R., Mcquiston, C., Palik, B., Reich, P.B., Turner, C., White, M., Adams, C., D'amato, A., Hagell, S., Johnson, P., Johnson, R., Larson, M., Matthews, S., Montgomery, R., Olson, S., Peters, M., Prasad, A., Rajala, J., Daley, J., Davenport, M., Emery, M.R., Fehringer, D., Hoving, C.L., Johnson, G., Johnson, L., Neitzel, D., Rissman, A., Rittenhouse, C., Ziel, R. (Eds.), Secondary Minnesota Forest Ecosystem Vulnerability Assessment and Synthesis: A Report from the Northwoods Climate Change Response Framework Project. GTR NRS-133. USDA Forest Service Northern Research Station.
Hayhoe, K., Vandorn, J., Croley Ii, T., Schlegal, N., Wuebbles, D., 2010. Regional climate change projections for Chicago and the US Great Lakes. J. Great Lakes Res. 36 (Supplement 2), 7–21. https://doi.org/10.1016/j.jglr.2010.03.012.
Head, L., Atchison, J., Gates, A., Muir, P., 2011. A fine-grained study of the experience of drought, risk and climate change among Australian wheat farming households. Ann. Assoc. Am. Geogr. 101, 1089–1108. https://doi.org/10.1080/00045608.2011.579533.
Hubbart, J.A., Guyette, R., Muzika, R.-M., 2016. More than drought: precipitation variance, excessive wetness, pathogens and the future of the western edge of the eastern deciduous forest. Sci. Total Environ. 566–567, 463–467. https://doi.org/10.1016/j.scitotenv.2016.05.108.
Irland, L.C., Adams, D., Alig, R., Betz, C.J., Chen, C.-C., Hutchins, M., Mccarl, B.A., Skog, K.E.N., Sohngen, B.L., 2001. Assessing socioeconomic impacts of climate change on US forests, wood-product markets, and forest recreation. BioScience 51, 753–764. https://doi.org/10.1641/0006-3568(2001)051[0753:asiocc]2.0.co;2.
Janowiak, M.K., Iverson, L.R., Mladenoff, D.J., Peters, E., Wythers, K.R., Xi, W., Brandt, L.A., Butler, P.R., Handler, S.D., Shannon, P.D., Swanston, C., Parker, L.R., Amman, A.J., Bogaczyk, B., Handler, C., Lesc, E., Reich, P.B., Matthews, S., Peters, M., Prasad, A., Khanal, S., Liu, F., Bal, T., Bronson, D., Burton, A., Ferris, J., Fosgitt, J., Hagan, S., Johnston, E., Kane, E., Matula, C., O'connor, R., Higgins, D., Pierre, M.S., Daley, J., Davenport, M., Emery, M.R., Fehringer, D., Hoving, C.L., Johnson, G., Neitzel, D., Notaro, M., Rissman, A., Rittenhouse, C., Ziel, R., 2014a. Forest ecosystem vulnerability assessment and synthesis for Northern Wisconsin and Western Upper Michigan: a report from the northwoods climate change response framework project. Secondary. In: JANOWIAK, M.K., Iverson, L.R., Mladenoff, D.J., Peters, E., Wythers, K.R., Xi, W., Brandt, L.A., Butler, P.R., Handler, S.D., Shannon, P.D., Swanston, C., Parker, L.R., Amman, A.J., Bogaczyk, B., Handler, C., Lesc, E., Reich, P.B., Matthews, S., Peters, M., Prasad, A., Khanal, S., Liu, F., Bal, T., Bronson, D., Burton, A., Ferris, J., Fosgitt, J., Hagan, S., Johnston, E., Kane, E., Matula, C., O'connor, R., Higgins, D., Pierre, M.S., Daley, J., Davenport, M., Emery, M.R., Fehringer, D., Hoving, C.L., Johnson, G., Neitzel, D., Notaro, M., Rissman, A., Rittenhouse, C., Ziel, R. (Eds.), Secondary Forest Ecosystem Vulnerability Assessment and Synthesis for Northern Wisconsin and Western Upper Michigan: A Report from the Northwoods Climate Change Response Framework Project. GTR NRS-136. USDA Forest Service Northern Research Station.
Janowiak, M.K., Swanston, C.W., Nagel, L.M., Brandt, L.A., Butler, P.R., Handler, S.D., Shannon, P.D., Iverson, L.R., Matthews, S.N., Prasad, A., PeterS, M.P., 2014b. A practical approach for translating climate change adaptation principles into forest management actions. J. For. 112, 424–433. https://doi.org/10.5849/jof.13-094.
Joyce, L., Blate, G., Mcnulty, S., Millar, C., Moser, S., Neilson, R., Peterson, D., 2009. Managing for multiple resources under climate change: national forests. Environ. Manage. 44, 1022–1032. https://doi.org/10.1007/s00267-009-9324-6.
Juhola, S., Glaas, E., Linnér, B.-O., Neset, T.-S., 2016. Redefining maladaptation. Environ. Sci. Policy 55, 135–140. https://doi.org/10.1016/j.envsci.2015.09.014.
Kates, R.W., Travis, W.R., WilbankS, T.J., 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. Proc. Natl. Acad. Sci. 109, 7156–7161. https://doi.org/10.1073/pnas.1115521109.
Keenan, R.J., 2015. Climate change impacts and adaptation in forest management: a review. Ann. For. Sci. 72, 145–167. https://doi.org/10.1007/s13595-014-0446-5.
Kelly, P.M., Adger, W.N., 2000. Theory and practice in assessing vulnerability to climate change and facilitating adaptation. Clim. Change 47, 325–352. https://doi.org/10.1023/a:1005627828199.
King, D., Bird, D., Haynes, K., Boon, H., Cottrell, A., Millar, J., Okada, T., Box, P., Keogh, D., Thomas, M., 2014. Voluntary relocation as an adaptation strategy to extreme weather events. Int. J. Disaster Risk Reduct. 8, 83–90. https://doi.org/10.1016/j.ijdrr.2014.02.006.
Klein, R.J., 2003. Adaptation to climate variability and change: what is optimal and appropriate. In: SCHECHTER, C.G.A.M. (Ed.), Climate Change in the Mediterranean: Socio-Economic Perspectives of Impacts, Vulnerability and Adaptation. Edward Elgar, Cheltenham, UK.
Kolström, M., Lindner, M., Vilén, T., Maroschek, M., Seidl, R., Lexer, M.J., Netherer, S., Kremer, A., Delzon, S., Barbati, A., Marchetti, M., Corona, P., 2011. Reviewing the science and implementation of climate change adaptation measures in European forestry. Forests 2, 961.
Krueger, R., Casey, M.A., 2015. Focus Groups: A Practical Guide for Applied Research. Sage Publications, Thousand Oaks.
Lal, P., Alavalapati, J.R., Mercer, E., 2011. Socio-economic impacts of climate change on rural United States. Mitigat. Adapt. Strat. Global Change 16, 819–844. https://doi.org/10.1007/s11027-011-9295-9.
Lawrence, A., Marzano, M., 2014. Is the private forest sector adapting to climate change? A study of forest managers in north Wales. Ann. For. Sci. 71, 291–300. https://doi.org/10.1007/s13595-013-0326-4.
Lindell, M.K., Perry, R.W., 2012. The protective action decision model: theoretical modifications and additional evidence. Risk Anal. 32, 616–632. https://doi.org/10.1111/j.1539-6924.2011.01647.x.
Md Mustafa, S., JayanT, K.R., 2010. In situ adaptation against sea level rise (SLR) in Bangladesh: does awareness matter? Int. J. Clim. Change Strategies Manage. 2, 321–345. https://doi.org/10.1108/17568691011063079.
Mendelsohn, R., 2000. Efficient adaptation to climate change. Clim. Change 45, 583–600. https://doi.org/10.1023/a:1005507810350.
Miles, M.B., Huberman, A.M., Saldana, J., 2014. Qualitative Data Analysis: A Methods Sourcebook. Sage Publications, Los Angeles.
Millar, C.I., Stephenson, N.L., 2015. Temperate forest health in an era of emerging megadisturbance. Science 349, 823–826. https://doi.org/10.1126/science.aaa9933.
Millar, C.I., Stephenson, N.L., Stephens, S.L., 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecol. Appl. 17, 2145–2151. https://doi.org/10.1890/06-1715.1.
Moser, S.C., 2010. Now more than ever: the need for more societally relevant research on vulnerability and adaptation to climate change. Appl. Geogr. 30, 464–474. https://doi.org/10.1016/j.apgeog.2009.09.003.
Moser, S.C., Dilling, L., 2004. Making climate hot. Environ.: Sci. Policy Sustain. Dev. 46, 32–46.
Nguyen, Q., Hoang, M.H., Öborn, I., Van Noordwijk, M., 2013. Multipurpose agroforestry as a climate change resiliency option for farmers: an example of local adaptation in Vietnam. Clim. Change 117, 241–257. https://doi.org/10.1007/s10584-012-0550-1.
Opiyo, F., Wasonga, O., Nyangito, M., Schilling, J., Munang, R., 2015. Drought adaptation and coping strategies among the Turkana pastoralists of Northern Kenya. Int. J. Disaster Risk Sci. 6, 295–309. https://doi.org/10.1007/s13753-015-0063-4.
Osbahr, H., Twyman, C., Neil Adger, W., Thomas, D.S.G., 2008. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. Geoforum 39, 1951–1964. https://doi.org/10.1016/j.geoforum.2008.07.010.
Park, S.E., Marshall, N.A., Jakku, E., Dowd, A.M., Howden, S.M., Mendham, E., Fleming, A., 2012. Informing adaptation responses to climate change through theories of transformation. Global Environ. Change 22, 115–126. https://doi.org/10.1016/j.gloenvcha.2011.10.003.
Patton, M.Q., 2002. Qualitative Research and Evaluation Methods. Sage Publications,

Thousand Oaks, CA.
Pelling, M., O'brien, K., Matyas, D., 2015. Adaptation and transformation. Clim. Change 133, 113–127. https://doi.org/10.1007/s10584-014-1303-0.
Poland, T.M., Mccullough, D.G., 2006. Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. J. For. 104, 118–124.
Potter-Witter, K., 2005. A cross-sectional analysis of Michigan nonindustrial private forest landowners. North. J. Appl. For. 22, 132–138.
Pugh, S.A., Pedersen, L.D., Heym, D.C., Piva, R.J., Woodall, C.W., Barnett, C.J., Kurtz, C.M., Moser, W.K., 2009. Michigan's Forests 2009. Forest Service Northern Research Station.
QSR INTERNATIONAL PTY LTD, 2012. NVivo Qualitative Data Analysis Software.
Quinn, T., Adger, W.N., 2011. Climate change when you are getting on in life. Environ. Plann. A: Econ. Space 43, 2257–2260. https://doi.org/10.1068/a44372.
Raymond, C.M., Robinson, G.M., 2013. Factors affecting rural landholders' adaptation to climate change: insights from formal institutions and communities of practice. Global Environ. Change 23, 103–114. https://doi.org/10.1016/j.gloenvcha.2012.11.004.
Reckwitz, A., 2002. Toward a theory of social practices: a development in culturalist theorizing. Eur. J. Soc. Theory 5, 243–263. https://doi.org/10.1177/13684310222225432.
Reser, J.P., Swim, J.K., 2011. Adapting to and coping with the threat and impacts of climate change. Am. Psychol. 66, 277–289.
Rogers, R.W., 1975. A protection motivation theory of fear appeals and attitude change. J. Psychol. 91, 93–114. https://doi.org/10.1080/00223980.1975.9915803.
Schatzki, T.R., 1997. Practices and actions a wittgensteinian critique of Bourdieu and Giddens. Philos. Soc. Sci. 27, 283–308. https://doi.org/10.1177/004839319702700301.
Schreier, M., 2014. Qualitative content analysis. In: FLICK, U. (Ed.), The SAGE Handbook of Qualitative Data Analysis. SAGE Publications Ltd., London.
Seidl, R., Thom, D., Kautz, M., Martin-Benito, D., Peltoniemi, M., Vacchiano, G., Wild, J., Ascoli, D., Petr, M., Honkaniemi, J., 2017. Forest disturbances under climate change. Nat. Clim. Change 7, 395–402.
Shameem, M.I.M., Momtaz, S., Kiem, A.S., 2015. Local perceptions of and adaptation to climate variability and change: the case of shrimp farming communities in the coastal region of Bangladesh. Clim. Change 133, 253–266. https://doi.org/10.1007/s10584-015-1470-7.
Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. Global Environ. Change 16, 282–292. https://doi.org/10.1016/j.gloenvcha.2006.03.008.
Smit, B., Burton, I., Klein, R.J.T., Street, R., 1999. The science of adaptation: a framework for assessment. Mitigat. Adapt. Strat. Global Change 4, 199–213. https://doi.org/10.1023/a:1009652531101.
Smit, B., Burton, I., Klein, R.J.T., Wandel, J., 2000. An anatomy of adaptation to climate change and variability. Clim. Change 45, 223–251. https://doi.org/10.1023/a:1005661622966.
Sober, E., 1993. The Nature of Selection: Evolutionary Theory in Philosophical Focus. University of Chicago Press, Chicago.
Sousa-Silva, R., Ponette, Q., Verheyen, K., Van Herzele, A., Muys, B., 2016. Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. For. Ecosyst. 3, 22. https://doi.org/10.1186/s40663-016-0082-7.
Swim, J., Clayton, S., Doherty, T., Gifford, R., Howard, G., Reser, J., Stern, P., Weber, E., 2009. Psychology and Global Climate Change: Addressing a Multi-Faceted Phenomenon and Set of Challenges. A Report by the American Psychological Association's Task Force on the Interface between Psychology and Global Climate Change. American Psychological Association, Washington.
Thomsen, D.C., Smith, T.F., Keys, N., 2012. Adaptation or manipulation? Unpacking climate change response strategies. Ecol. Soc. 17. https://doi.org/10.5751/ES-04953-170320.
Tompkins, E.L., Eakin, H., 2012. Managing private and public adaptation to climate change. Global Environ. Change 22, 3–11. https://doi.org/10.1016/j.gloenvcha.2011.09.010.
Toole, S., Klocker, N., Head, L., 2016. Re-thinking climate change adaptation and capacities at the household scale. Clim. Change 135, 203–209. https://doi.org/10.1007/s10584-015-1577-x.
Truelove, H.B., Carrico, A.R., Thabrew, L., 2015. A socio-psychological model for analyzing climate change adaptation: a case study of Sri Lankan paddy farmers. Global Environ. Change 31, 85–97. https://doi.org/10.1016/j.gloenvcha.2014.12.010.
Van Gameren, V., Zaccai, E., 2015. Private forest owners facing climate change in Wallonia: adaptive capacity and practices. Environ. Sci. Policy 52, 51–60. https://doi.org/10.1016/j.envsci.2015.05.004.
Wheeler, S., Zuo, A., Bjornlund, H., 2013. Farmers' climate change beliefs and adaptation strategies for a water scarce future in Australia. Global Environ. Change 23, 537–547. https://doi.org/10.1016/j.gloenvcha.2012.11.008.
Wise, R.M., Fazey, I., Stafford Smith, M., Park, S.E., Eakin, H.C., Archer Van Garderen, E.R.M., Campbell, B., 2014. Reconceptualising adaptation to climate change as part of pathways of change and response. Global Environ. Change 28, 325–336. https://doi.org/10.1016/j.gloenvcha.2013.12.002.
Wolf, J., Moser, S.C., 2011. Individual understandings, perceptions, and engagement with climate change: insights from in-depth studies across the world. Wiley Interdiscip. Rev. Clim. Change 2, 547–569. https://doi.org/10.1002/wcc.120.
Wolf, J., Adger, W.N., Lorenzoni, I., Abrahamson, V., Raine, R., 2010. Social capital, individual responses to heat waves and climate change adaptation: an empirical study of two UK cities. Global Environ. Change 20, 44–52.
Wood, S.A., Jina, A.S., Jain, M., Kristjanson, P., Defries, R.S., 2014. Smallholder farmer cropping decisions related to climate variability across multiple regions. Global Environ. Change 25, 163–172. https://doi.org/10.1016/j.gloenvcha.2013.12.011.
Zheng, Y., Dallimer, M., 2016. What motivates rural households to adapt to climate change? Clim. Dev. 8, 110–121. https://doi.org/10.1080/17565529.2015.1005037.